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SOIL CONSERVATION SERVICE
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INTRODUCTORY CHAPTER OF PROPOSED

REGIONAL ENGINEERING HANDBOOK

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INTRODUCTION

Purpose and Scope

The purpose of this handbook is to present the best information now available on the application of engineering principles to the problem of soil and water conservation in Region 8. It is intended primarily for the use of the engineering staff, and its effective use is dependent upon a thorough understanding of the general problems involved. The attached diagram "Accelerated Erosion Pattern in the Southwest" attempts to outline the situation as it exists in Region 8.

General Problem

Misuse or improper management of the land results in the loss of fertile and productive topsoil. Continued action of wind and water on denuded or partially denuded slopes results in further losses and, unless checked, destruction of land, vegetative cover, and crops is accelerated.

In the Southwest, where the annual precipitation is low, farming is dependent largely upon flood or storage irrigation. Sedimentation of channels and storage reservoirs directly and indirectly affect farming activities through inundation, infertile overwash, bank cutting, and by the loss of available water supply through decreased storage facilities and evaporation.

Removal of soil from watersheds not only results in destruction of valuable forest, range, and farm land; deposition of this soil in streams and reservoirs also threatens land and improvements below.

The diagram emphasizes the complexity of the situation, the importance of the watershed as the unit of treatment, and the necessity for close coordination between ranchers, farmers, conservationists, foresters, range men, agronomists, soils specialists, and engineers in attacking the problem.

Control of erosion at its source, or as close to its source as possible under existing conditions, is the primary objective of the Soil Conservation Service.

The critical condition of soil erosion and the destructive concentrations of precipitation into surface run-off have been brought about by a disregard of the dictates of Nature. Consequently, a logical approach to the problem of rehabilitation and stabilization is through a return to the natural pattern of conservation. Treatment measures, therefore, should employ a minimum departure from natural processes and priority should be accorded to work of vegetative character.

Engineers' Relation to the Problem

Proper range management which is concerned with the maintenance of a protective vegetative cover is prerequisite to erosion control on range land and forest land in the Southwest. Under certain critical conditions of erosion and vegetative cover, where the return to erosional stability by vegetative measures is too uncertain or too slow, mechanical or structural measures may be necessary as supplementary treatment. The necessity for protection of soil from the erosive action of wind and water has long been recognized by engineers. Since vegetation protects the underlying soil from the action of wind and water, engineers, as well as range men, are interested in the maintenance of an adequate cover, and engineers should be prepared to render such supplementary assistance as is necessary in the way of structural treatment.

The application of proper farming and irrigation practices on farm lands is recognized as prerequisite to erosion control on crop land, but structural or mechanical measures may be necessary to supplement the agronomic treatment.

Structural or mechanical treatment has, therefore, an important function in the program of soil and water conservation in Region 8. Because of the close tie between the various types of treatment, engineers should have a working knowledge of all practices involved.

It should be recognized that any guide or handbook prepared at this time is subject to periodic revision because approved practices are constantly changing as the result of further experimentation.

EROSION CONTROL TREATMENT INVOLVING STRUCTURAL MEASURES

Classification According to Benefits

As stated previously, the primary objective of soil and water conservation activities in Region 8, as elsewhere, is the control of erosion at its source, or as close to its source as is possible under existing conditions. Necessary control measures may, for the purpose of justification, be classified under three general headings, namely: 1) those which primarily benefit the land under treatment; 2) those which primarily benefit other land and improvements; and 3) those which benefit equally land under treatment and other land and improvements. Structural measures which fall in the first class are largely those used to supplement vegetative measures and include fences (boundary, division, and exclosure), stock-water development (tanks, wells, and springs), terracing, reseeding, and water retardation or water spreading structures (contour furrows, crescents, dikes, diversion dams, percolators, and spreaders) when the intensity is such as to primarily benefit the land under treatment.

Structural measures which fall within the second class include detention dams, soil-saving dams, and major water spreading systems when used primarily to protect other lands and improvements from cutting, sedimentation, or inundation.

Structural measures which fall within the third class include: a) many of those listed in the first class when used more intensively in order to protect other land and improvements in addition to the land under treatment; b) stock tanks, soil-saving dams and detention dams when used to stabilize land under treatment as well as to protect other land and improvements; c) bank protection structures such as levees, revetments, stream bottom fencing, tetrahedrons, etc.

Responsibility for the determination of the need, general type, intensity, and justification of structural measures outlined above rests with all technicians involved in the preparation of the plan of conservation operations. Responsibility for the selection of the specific type of treatment, and its design, rests with the engineer assisted, when necessary, by the soils specialist.

Justifiable Intensity of Structural Treatment

All technicians are concerned with the question of justifiable intensity of structural treatment. The answer to this question involves the following factors, some of which can be determined only after further experimentation:

1. Land classification according to erosional activity, production potential, and use.

2. General and specific objectives of treatment.

3. Results which may be expected, using various types and intensities of treatment.

4. Costs of various types and intensities and their relation to immediate as well as ultimate benefits.

Lacking definite information on all the above factors, technicians should base their recommendations on the minimum requirements under known conditions and known objectives. If the advisability of a structure is questionable, its building should be postponed until such time as the need has been demonstrated. Structural measures indicated by the minimum requirements should fall well within the limits of justifiable expenditures.

Specific Types of Structural Control Measures

In the following paragraphs an attempt has been made to classify and discuss specific types of erosion control

measures in such a manner as will assist engineers in selecting proper and justifiable types of treatment under various conditions. Engineers are, in general, concerned with three classes of treatment, namely; extensive, intensive, and special.

Extensive treatment involves the widespread application of control measures to a large area with no special concentration at one point. The expenditures for such measures are properly chargeable to the area as a whole.

Intensive treatment involves the application of supplemental control measures to specific areas within a larger unit. The expenditures for such measures are properly chargeable to the smaller area treated or benefited.

Special treatment involves the application of special control measures to particular watershed problems. The expenditures for these measures are properly chargeable to lands and improvements which derive benefit from the treatment.

Extensive Treatment of Range and Forest Lands

Extensive treatment of range and forest lands involves the application of proper range and woodland management to large or small ranch units. Proper range and woodland management includes stock-water development, fencing, roads, trails, and other measures which directly and indirectly improve facilities for better livestock distribution.

Actual location and design of stock-water development (stock tanks, springs, and wells) are the responsibility of the engineer, soils expert, and/or geologist after the range technician has indicated the general location and type. Engineers should consider costs of initial development and maintenance when comparing sites and types, and should attempt to hold costs within the justifiable limits set up by the range technician unless additional justification can be furnished by the direct use of the structure for erosion control. Engineers should, where possible, locate stock tanks or charcos so that they can serve the dual purpose of providing stock water and erosion control. In the design of stock tanks and charcos extreme care should be taken to avoid an erosion hazard such as head cutting induced by flow into the borrow pit or charco. (Other factors involved in the location and design of stock tanks are covered in Regional Memoranda #87 and #120.)

Fencing, when considered as a structural control measure under extensive treatment, includes the following types: boundary, division, and exclosure (if in connection with stock tanks, wells, and springs). The engineers' concern in regard to a fencing program is its location and construction. (Reference is made to SCS Field Memorandum #602 relative to fencing on privately owned and public lands.)

A road or trail system is generally necessary to facilitate construction activities as well as range and woodland administration. In all areas a study should be made of both the present and the proposed road system to determine adequate provisions for the control of erosion. This is particularly true where established roads have been improperly located. Such a study may show the necessity of relocating roads on ridges or on more stable soil, and the need for special control structures such as water bars, drainage dikes, drop inlets to culverts, etc. The determination of the proper road system within an agreement area is the responsibility of all technicians, but the specific location, design, and construction of the final system are the responsibility of the engineers.

Extensive Treatment of Cultivated Lands

Extensive treatment of cultivated lands (dry farms and irrigated farms) involves the application of proper farming practices over the entire area. No structural control measures are included under this classification, and, therefore, engineers are not directly concerned with such extensive treatment measures.

Intensive Treatment of Cultivated Lands

Intensive treatment of cultivated lands (dry farms and irrigated farms) serves to supplement proper farming practices with necessary structural measures, such as terraces, terrace outlets, contour listing, basin listing, contour irrigation structures, diversion dams, dikes and ditches, check dams, bank sloping, and other gully control structures. As an aid to the restoration and stabilization of gullies in agricultural areas where land values are high, more intensive structural treatment may be justified than on range lands. Prevention of gully erosion on sloping, irrigated lands involves a redesign of irrigation systems with the conversion of "down the slope irrigation" to "contour irrigation" and some control of waste water.

Careful consideration should be given to the control of wind erosion on cultivated lands. Many of the structures listed above will supplement proper farming practices through water retardation and increased moisture penetration, thereby controlling both wind and water erosion.

The need, general type, justification, and intensity of structural treatment on cultivated lands should be determined by the planning group as a whole. The selection and design of the specific type should be the responsibility of the engineer, assisted when necessary by the soils technician.

Intensive Treatment of Range and Forest Lands

Intensive treatment of range and forest lands serves to supplement extensive treatment on certain areas through increasing the distribution and absorption of moisture and by controlling active cutting in gullies.

The determination of the need, justification, and general type of intensive treatment is the responsibility of the entire planning group. The recommendations of this group will include, in general, the use of water retardation, water spreading, and gully control structures where necessary to: 1) speed up the return of the vegetative cover through control of excessive run-off; 2) prevent concentration of run-off in small gullies and depressions; 3) provide additional moisture to critical areas which have a high production potential; 4) control of active bed, lateral, and head erosion; 5) protect land and improvements below from active cutting or sedimentation.

The selection and design of the specific structural measures involved are the responsibility of the engineering technician assisted when necessary by the soils technician.

Water retardation and water spreading, with subsequent absorption, are accomplished by contour furrows, subsoiling, chiseling, crescents, percolators (brush, rock, wire, or combinations), detention dams, diversion dams, dikes, weeps, diversion ditches, water bars and spreaders (concrete, masonry, burlap sacks, etc.). Combinations of these measures in addition to fences, check dams, soil-saving dams, drops or chutes are used to control bed cutting or active head and lateral cutting caused by overpour. (Active cutting caused by undermining is considered under the heading of special treatment.)

The specific type of treatment is determined by known soil conditions, slopes, topography, amount and intensity of run-off, amount, type and density of vegetation, and availability of materials for construction.

In considering the diversion and spreading of water, special emphasis is placed on the need for a careful study of both tributary drainage and spreading area. It is extremely important to determine the relation between the amount of run-off; the intensity of run-off; the amount of silt; the size of the spreading area, its slope, its ability to absorb water; and the effect upon it of a heavy silt deposition. Such probloms as the control of excess water, the continued spreading of water and silt, and the selection of the proper type of diversion structure (partial or complete diversion) are also involved.

The above paragraph applies, in general, to the diversion and spreading of large uncontrolled flows. The diversion and spreading of those flows which may be diverted directly from the gully by numerous furrows or small ditches and spread without danger of cutting should also be considered.

Intensive structural treatment for the control of wind erosion calls for many of the same structures as are outlined above. Such structures as contour furrows, crescents,

closed terraces, and percolators serve to increase moisture penetration and thereby the density and volume of the vegetative cover.

Wind breaks constructed of woven wire fencing and lathes should be considered in supplementing natural wind breaks. Temporary fencing with rigid livestock control should receive careful consideration.

Guide to Selection of Specific Structures Under Stated Conditions

In general, each situation in the field has its individual problems, and it is impossible to outline definite rules which may be applied in each instance to the selection of the proper structures. To assist in such selection, however, each of the five conditions outlined is discussed briefly as to the use and priority of use of certain structures.

1. Structures Necessary to Speed up the Return of the Vegetative Cover through Control of Excessive Run-off. The immediate objective is to retard the flow in order that moisture penetration may be sufficiently increased to insure the production of an adequate vegetative cover. If soil conditions permit (see Regional Memorandum #119), contour furrows, subsoiling, or chiseling should receive first consideration as the most economical measure for water retardation. Where there is excessive run-off from above, special emphasis should be placed on the depressed furrow or similar structure in order to avoid the danger of breaks in ridges. It may also be necessary to consider the use of an earth dike above such treatment either to divert excess flows away from the furrowed area or to release such flows at special points through use of weeps protected by spreaders. Crescents should be considered on the flatter slopes where it may be desirable to impound additional water for the protection of critical areas immediately below. If soil conditions and topography do not warrant the use of furrows, various types of percolators, such as brush, rock, wire, or combinations, should receive consideration. Availability of materials for construction will usually determine the specific type.

In the design and construction of the above listed measures, special attention should be given to certain factors: such as spreading of furrow slice, breaking or damming of furrows, turning furrows up at gullies, wiring down percolators that will be subject to heavy flows, borrow pits below dikes where the lower edge can be maintained on the contour, and broken instead of continuous borrow pits.

2. Structures Necessary to Prevent Concentration of Run-off in Small Gullies and Depressions. The immediate objective is to divert and spread the water in order to prevent

concentrations of run-off that would cause active cutting. Diversion dams and dikes with weeps at selected points and spreaders at the ends of each dike, combined with retardation structures as outlined above, should be considered. Points of diversion should be carefully selected, and partial diversions should be used only when it is obviously impossible to divert or spread the entire flow. Diversion ditches may also be used in connection with spreaders and retardation structures. Percolators and spreaders used in conjunction with impervious structures across small gullies should receive consideration where there is no great amount of added run-off from above. Temporary fencing of such areas, also, should be considered.

In the design and construction of the above listed structures, special attention should be given to such factors as freeboard of dams and dikes; the possible effect of future silting; permanent protection at the end of each earth structure to prevent scour; excessive cross section necessary to minimize the effect of rodents; and 6" maximum height of spreaders and percolators.

3. Structures Necessary to Provide Additional Moisture to Critical Areas which have a High Production Potential. This problem may involve the diversion of water from existing gullies or from areas of low production potential to areas of high production potential where it is possible to spread the water and allow it to penetrate into the soil. In the first instance, the partial or complete diversion dam may be necessary, depending upon the quantity of water and the size of the spreading area. The possibility of spreading small quantities of water diverted from the gully by numerous ditches on both sides should also be considered. In the second instance, an intercepting dike with small weeps may be used. Other structures required are similar to those discussed in the preceding paragraphs. Fencing of these spreading areas, in order to obtain rigid livestock control, should be considered.

4. Structures Necessary to Control Active Bed, Lateral, and Head Erosion. Control of active head and lateral erosion is of the greatest importance not only because of the fertile valleys which are being destroyed rapidly through cutting, but also because of the immense quantities of silt which are being transported and deposited along channels and in reservoirs. Recommendations by the planning group for structural measures in the control of active bed, lateral, and head erosion should indicate that the group had previously given careful consideration to the possibilities of control through the use of vegetative measures under proper range management. On this basis, engineers should then consider minimum structures required to supplement vegetativ

measures. First, they should consider the effect of stream bottom fencing supplemented by plantings where the gradient is relatively flat and moisture is present.

Active bed cutting may be checked through the use of permanent check dams at selected points where it is feasible to establish a base level of cutting. However, as active head and lateral cutting caused by overpour will continue as long as water concentrates in the arroyo and has sufficient force to carry away the eroded material, every attempt should be made to prevent water from reaching the gully. The possibility of diverting all water before it reaches the point of active cutting should be carefully considered as this method not only checks further cutting but, also, by spreading of additional water on adjacent areas increases the vegetative cover. The quantity and intensity of run-off, the size, soils conditions, and topography of the spreading area determine the advisability and feasibility of diverting all or a portion of the total run-off. If only partial diversion is indicated, conditions above the point of cutting should be carefully investigated as to the advisability of additional retardation structures, such as contour furrows, percolators, crescents, detention dams, etc., which would cause increased infiltration.

Before considering other methods of control, the engineers should carefully check the economic justification of such treatment. If a head drop, or chute structure appears necessary and justifiable, the cost of the retardation and diversion structures mentioned above should be considered in relation to the increased size of the drop or chute structure.

If the water tends to concentrate immediately above the point of active cutting, the head of the gully should be protected by a concrete, masonry, or burlap sack spreader which will cause an even spill into the gully. In some instances, with head cuts in small drainages, this method of spreading is the only treatment required, or it may be used in conjunction with retardation structures above. The central drop or chute structure should be used only after all other methods of treatment have been carefully considered, and only permanent structures should be built.

5. Structures Necessary to Protect Land and Improvements Below from Active Cutting or Sedimentation. The primary purpose of the measures discussed under 1, 2 and 3 above is the rehabilitation or improvement of the land under treatment. Only such spacing and locations should be considered as are 1) necessary to cause sufficient infiltration for the production of a vegetative cover that will be adequate to control erosion and 2) necessary to prevent return of run-off to arroyos after diversion. Closer spacing and additional

structures may appear advisable when the need has been demonstrated. The purpose of the measures discussed under 4 and 5 is concerned not only with rehabilitation or improvement of the land treated but with the protection of land and improvements below.

A more intensive treatment by such measures as are proposed in 1, 2, and 3 may be used to control movement of silt which is damaging land and improvements below and to control excessive run-off which, in passing through critical erosion areas, transports silt and debris to lower areas with the result that sedimentation and infertile overwash destroy valuable lands below.

Other structures which serve primarily to protect land and improvements below will be discussed under the heading of special treatment.

Special Treatment

Special treatment involves the application of special control measures, such as detention dams, retention dams, soil-saving dams, and miscellaneous bank protection measures. The effectiveness of these structures is measured by their control of excessive run-off, by their stabilization of active cutting in alluvial fill valleys, by their reduction in the silt load of flood flows, and by their protection to highly productive lands and improvements adjacent to the channel.

Emphasis is again placed on the secondary importance of most structural treatment and its dependence on proper land use in the upper watersheds. The purpose of special treatment measures is, of course, to supplement other treatment in establishing a vegetative cover adequate to prevent further accelerated erosion and in reducing the velocity and concentration of surface run-off. Careful consideration should be given to each individual structure in regard to its cost and the benefits to be derived from it. If any doubt exists as to the justification of the structure, its construction should be postponed until the need has been demonstrated.

Detention Dams. A detention dam may be defined as a dam built across a channel for the purpose of temporarily retarding excessive run-off and releasing a regulated flow through a conduit uncontrolled by valve or gate. This type of dam should be located only where it is possible to secure sufficient pondage to regulate uncontrolled flows which are causing damage below.

Indirect benefits of detention dams include the reduction of silt load, the improvement of vegetative cover both above and below the structure, and the possibility of spreading a controlled flow below the dam.

Attention should be called to the following factors: danger of cutting below by a regulated flow, need for constant maintenance especially during high water, possibility of flood-water rights below, and the need for desilting areas or stream bottom fencing above to control the rapidity of silting.

Retention Dams. A retention dam has for its primary purpose the impounding or storage of water. This type of dam plays an important part in the erosion control program in this Region as it impounds water for use of livestock, thereby providing for better livestock distribution. In some instances, a retention dam may be more effective than a detention dam in protecting critical erosion areas from excessive run-off, but in general its use, under such conditions, is limited to situations which do not involve questions as to water rights.

Soil-Saving Dams and Silt Barriers. Soil-saving dams and silt barriers, as the names imply, may be defined as dams built across a channel for the purpose of stabilizing silt-producing areas and of impounding silt which would otherwise be transported to the lower reaches. The location and site of each structure must be carefully selected with proper consideration of the channel gradient, the width of the valley floor above and below the structure, foundation conditions, and the amount and intensity of run-off. A flat gradient is the first requirement; otherwise, the quantity of silt impounded above the structure will not be sufficient to justify the cost. The width of the valley floor above the structure must be sufficient to permit the spreading of surplus water which will be forced out of the channel as a result of decreased velocity.

Existing conditions and the purpose of the structure will determine the type, such as drop inlet, pervious or impervious overpour, or diversion. The indirect benefits of the drop inlet type of structure are similar to those of the detention dam as outlined above. The use of the diversion type is limited to small drainages and to relatively large spreading areas. The over-pour type built in one or more lifts, depending on foundation conditions and depth of channel, will by-pass normal flows but will tend to force surplus water out of the channel during major flows as a result of decreased velocities and reduced cross-sectional areas. This structure, when properly located, will serve to stabilize active, lateral cutting, rebuild gullies, and impound silt; besides, by spreading excess water, it will increase vegetation without danger of sedimentation and cutting. Soil-saving dams and silt barriers should be considered only in connection with a complete erosion control program on the watershed in question.

The need and justification for such structures should be determined by the planning group as a whole. The selection of the proper type and the design are the responsibility of the engineer assisted by the soils technician. (For the design and construction of the drop inlet type of structure, reference is made to SCS-EP-14 "Design and Construction of the Drop Inlet Soil-Saving Dam" compiled by the engineering section in Washington.)

Bank Protection and Channel Stabilization Measures. As previously stated, lateral cutting, when caused by over-pour, may be considered as head cutting and treated accordingly. Where lateral cutting is the result of undermining by the stream flow itself and where natural or artificial revegetation alone will not suffice, it is necessary to resort to bank protection and other stabilization measures.

Necessary measures may be justified on the following bases: protection of highly productive agricultural lands, protection of improvements, and reduction in silting of channel and storage reservoirs. Some measures serve the dual purpose of checking further cutting and causing silt deposition between the bank and the structure.

The objective of channel stabilization is to establish a definite, low water channel and to permanently stabilize channel banks and bottoms of constant or intermittent streams or large washes by the use of mechanical structures, channel cut-offs across bends, and correlated, erosion control measures. In bank protection and channel stabilization, vegetation and mechanical structures are usually interdependent - the structure protects and fosters vegetation, and the plant growth makes for permanency of control. Planting of suitable trees or shrubs may obviate or modify the structural plan.

Well designed and strongly built structures are necessary to withstand high velocities and the force of flood water. The above factors and the amount of run-off expected must be considered and kept in mind at all times in the preparation of a plan for channel stabilization. Where stabilization work is to be done on channels of several miles in length, plans should be prepared before construction work is started to show the general alignment and location of various structures and the cut-offs over all or a large part of the channel. This is to assure a proper location of structures with regard to the general alignment.

No structures should be placed where they will obstruct a stream channel and reduce its capacity enough to produce local flood conditions. Neither should a structure be so placed, in regard to location and angle to stream flow, that while it corrects a condition at one place, it will cause damage in another.

Stream-bottom fencing to exclude livestock and to protect plantings should receive first consideration as a channel stabilization and bank protection measure. Other measures include jetties (rock, wire, rail, masonry, etc.), revetments (tetrahedrons, fences, rails, wire, rock, etc.), channel cut-offs, cut-off dams, bed stabilizers, and dikes.

The determination of the need and justification for bank protection and channel stabilization measures is the responsibility of the planning group as a whole. The selection of a specific type and its design are the responsibility of the engineer assisted, when necessary, by the soils technician.

Water Rights

The application of certain water retardation, water spreading, and gully control structures in this Region necessitates particular consideration of the water rights question. Water flowing in well-defined channels has, in general, been appropriated, and a careful investigation should be made with regard to its ultimate destination and use before any plans are prepared. As previously stated, retention of water for use of livestock is generally permissible. Diversion or retention of water flowing in a well-defined channel may be allowable if the channel disappears and the water, through natural spreading, is lost in the ground. Diversion or retention of water carrying a high percentage of silt may also be allowable if justified on the basis of silt damage below through sedimentation or infertile overwash. Such cases as the latter, however, should be referred to the regional office for approval.

The same consideration should be given to underground water rights in those states that require filings on underground water as well as on surface waters.

State Laws Covering Construction of Dams

Several states within this Region have state laws which require the state engineer's approval for all dams above a certain size. Some states require a state permit and state inspection on all such structures with the payment of a fee to cover state expenses. Engineers should be fully acquainted with all state laws bearing on the erosion control problem in their district or project.

It is impossible for the Soil Conservation Service to pay fees coveringpermits or inspections, but every attempt should be made to secure the state engineer's approval for all structures which fall within the statutes of the state. If the structure is to be built on privately owned land and for the primary benefit of the owner, the owner should be expected to obtain the necessary permits and pay the necessary fees.

Engineers should cooperate fully with the state engineer, and even if certain structures may not come under state statutes, all proposed measures of a special or unusual nature should be discussed with the state engineer and, if possible, his approval obtained. Plans and drawings covering all major or unusual structures should be forwarded to the state engineer's office in order that he may be informed as to the program within his state.